

AN ELECTRON BEAM TELEVISION RECORDER

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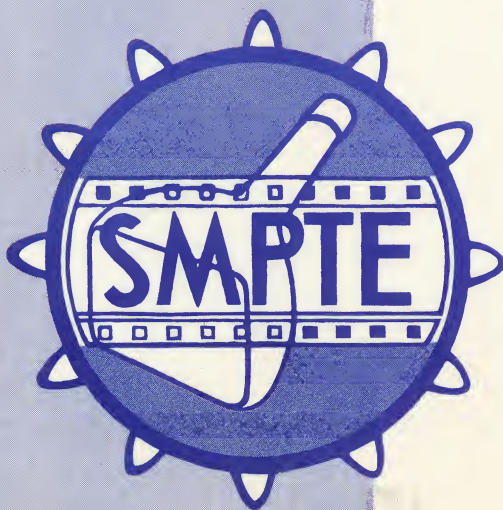
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Introduction

Conventional kinescope recording has a phosphor faceplate and light optical system as an interface between the electron beam carrying the television signal and the photographic film that will store the signal. The electron beam television recorder does away with the interface and brings the film inside the vacuum chamber where the electron beam can expose by direct bombardment into the film.

Because the vacuum system is periodically opened to atmosphere for the insertion and removal of film, several departures from conventional kinescope recording techniques are made. An obvious departure is the electron source which is now a heated tungsten hairpin filament. Tungsten does not contaminate as easily in atmosphere as do oxide cathodes. Imaging the apparent electron source on to the film target by means of a single magnetic lens places restrictions on the electron optical system.

Direct electron recording of a standard 525 line interlaced television signal on to a 16 mm format requires a small spot diameter if superior horizontal resolution is to be accomplished. Assuming equal line width and no space between lines, the placement of 525 lines on the standard 7.605 mm pitch of 16 mm film requires an electron spot size of approximately 14.5 microns. Shading considerations require that this spot focus be maintained over the entire raster. Also, since adjacent lines are displaced in time by 1/60 of a second, accurate beam placement

is required to preserve perfect interlace.

A second departure from conventional kinescope recording is in the intermittent motion of the film. The exposure of the film by the beam is essentially instantaneous so that more time in the recording cycle can be devoted to pull down and less to exposure. Conversion from 30 frames to 24 frames using the technique of counting out a full frame and discarding 1/4 field in the pull down interval means that in the 60 field per second system approximately 8 milliseconds is available for pull down and film setting before the exposure begins.

A third departure is the control of the exposure. Since the actual recording beam is available for metering, it is sampled during horizontal blanking for peak white when a reference pulse is analyzed. A servo system automatically readjusts the electron gun bias to maintain the proper peak signal. Set up of the black or pedestal exposure is done by observing the beam on an oscilloscope during the pull down interval. The film is not exposed during the horizontal blanking period or during pull down as the beam is deflected into a Faraday cage for measurement and servo control.

These three major departures together with other minor ones to be discussed later have made possible 16 mm television recordings free from the fixed noise patterns of phosphor faceplates, a resolution in excess of 600 lines, and pictures free from shutter bar.

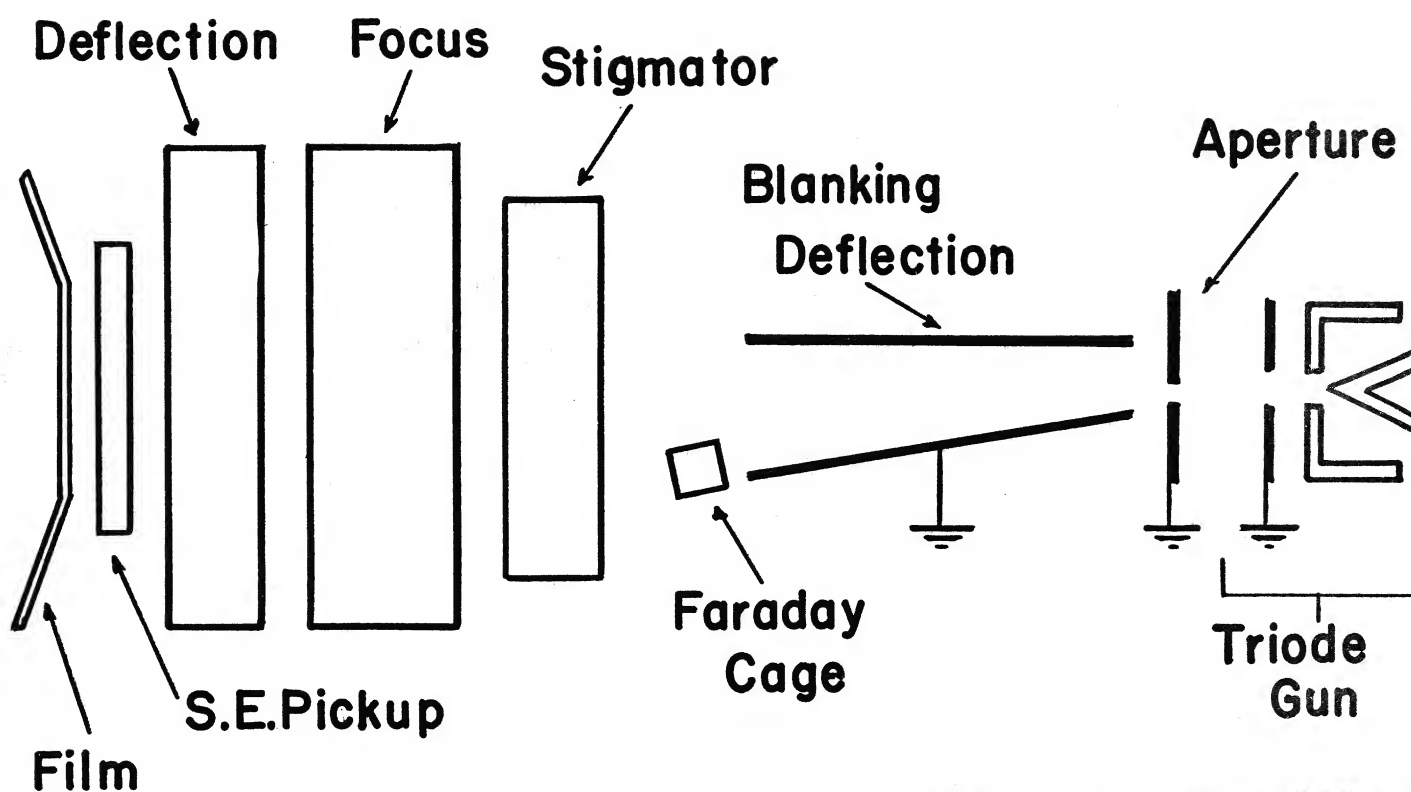


FIG.1 ELECTRON OPTICAL SYSTEM

Electron Optical System

The essential elements in forming and directing the electron beam are shown in Figure 1. The filament and grid of the simple triode gun are operated at about 18,000 volts negative to provide the necessary electron acceleration since the film target is most easily kept at zero or ground potential. The filament itself is a .006" diameter tungsten wire bent in the form of a sharp hairpin. The grid and filament structure is readily replaceable. The close spacing of the grid and anode provides a strong field to give a small beam cross-over which acts as the apparent electron source. A .010" diameter aperture limits the size of the beam bundle to reduce spherical aberration. These four elements form the beam bundle which is deflected and focused in the remainder of the optical system.

By the application of a negative voltage to the upper electrostatic deflector, the beam bundle is deflected into the Faraday cage. A negative voltage of about 250 volts is applied during composite blanking of the television signal and during the frame conversion or pull down of the film. Such a complete shut off of the beam from reaching the film is called "super-blanking" as contrasted to the blanking or pedestal level of the television signal at which the black exposure is made. Such a super-blanking deflection procedure results in a minimum of disturbance to the television signal applied to the grid of the electron gun.

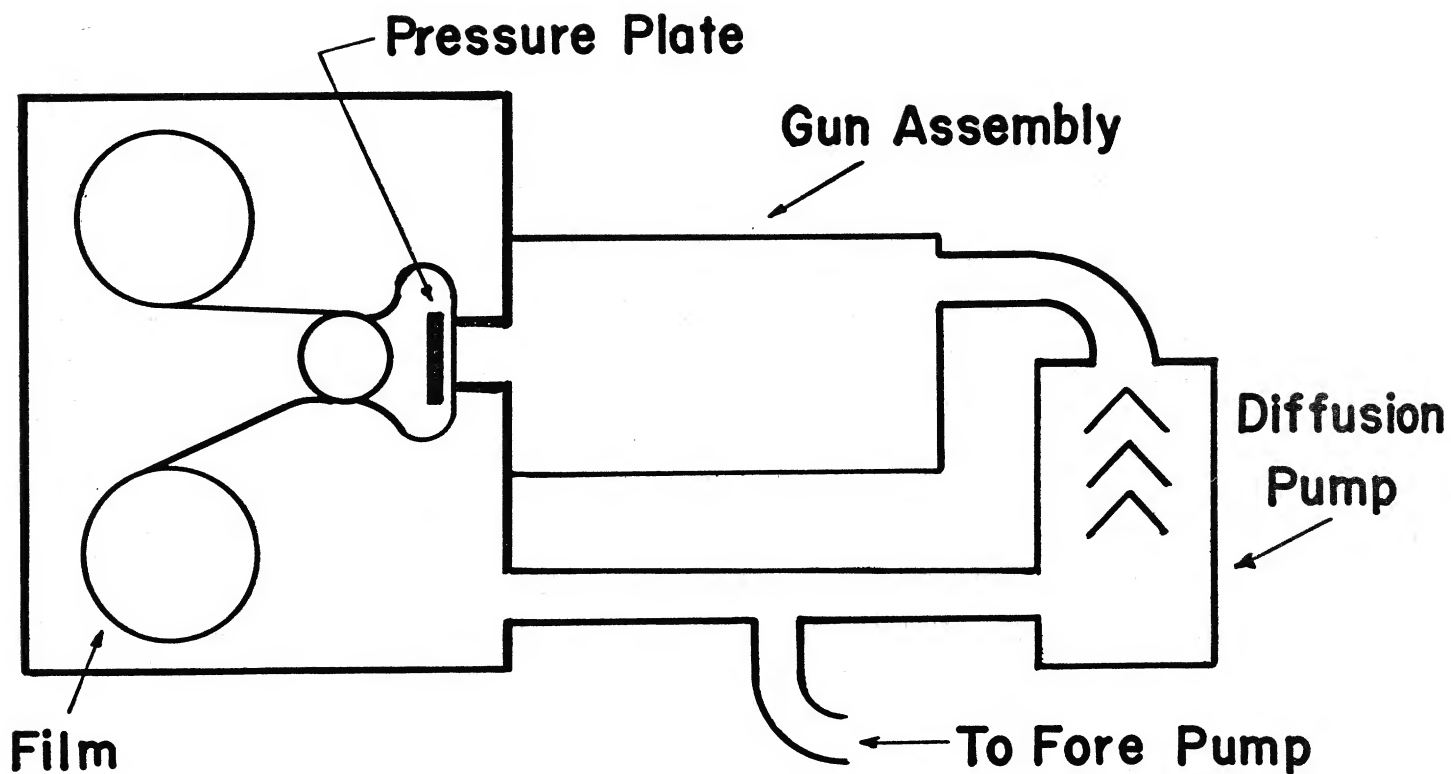


FIG.2 VACUUM SYSTEM

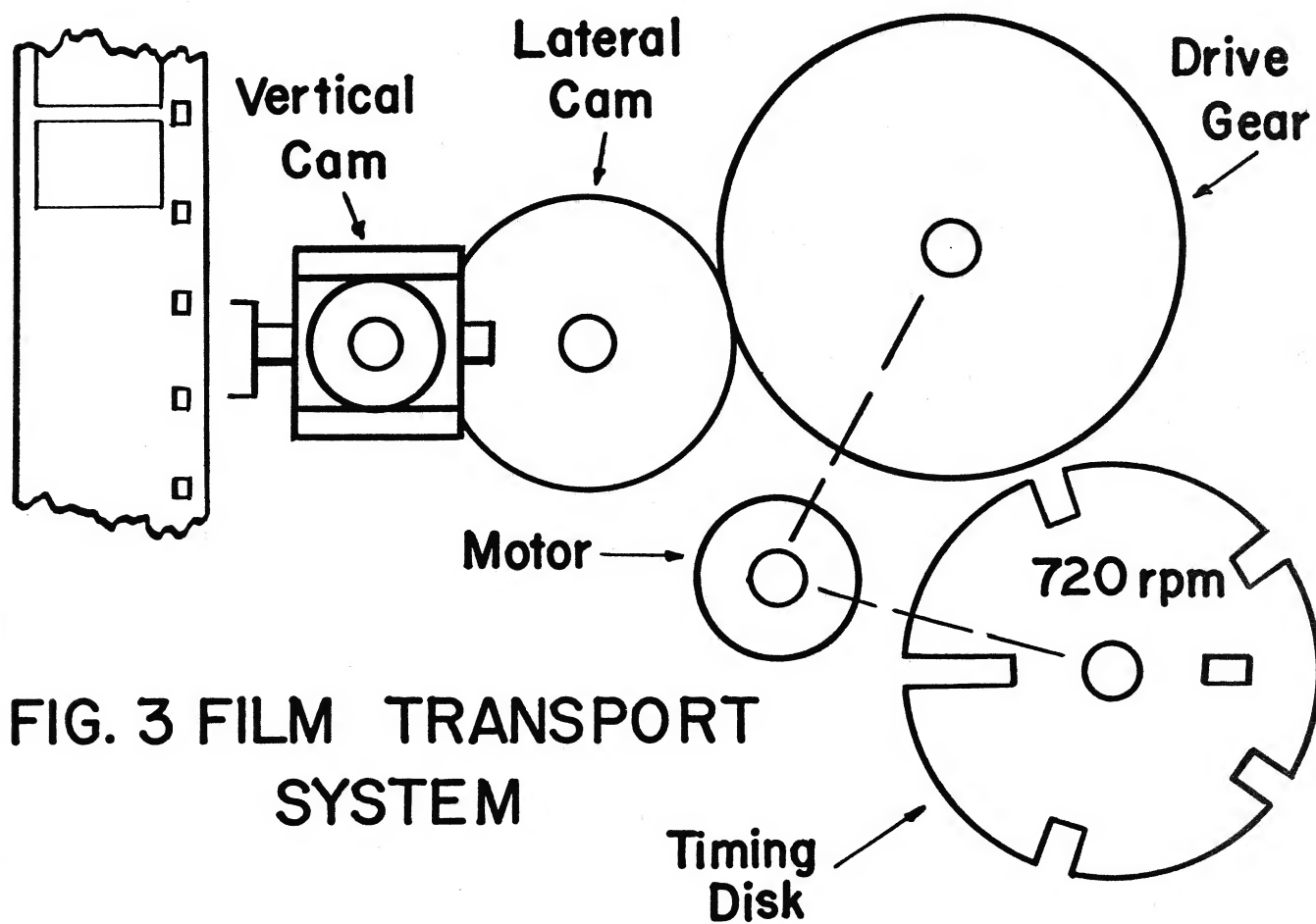


FIG. 3 FILM TRANSPORT SYSTEM

The stigmator corrects for unwanted astigmatism of the electron beam usually due to gun asymmetry. Controlled astigmatism is also introduced to mask discrete raster lines in the recorded film. A single magnetic lens is used to focus the beam to give a geometric reduction of the apparent source. Magnetic deflection for the television raster is used because of space and quality requirements. A secondary emission pickup ring is positioned close to the film target and used for focus and raster size adjustments in a manner similar to that used in a scanning probe microscope.

Vacuum System

Fast start up time or minimum pump-down time is achieved by placing the diffusion pump at the cathode end of the gun assembly as shown in Figure 2. A pressure plate holds the film in position for recording to minimize any film motion which would destroy interlace. Suitable valves (not shown) allow the gun to be kept at high vacuum during loading, exhaust, recording, and unloading operations.

Film Transport System

A simplified diagram of the film transport mechanism is shown in Figure 3. The shuttle mechanism has a pull down time of about 6 milliseconds with a low acceleration and deceleration cycle. The long pull down time helps in reducing film perturbations which give rise to line pairing in the recorded picture. The additional 2 milliseconds available before the new frame exposure begins is used for

settling time for the film to come to a complete rest.

Exposure, picture splicing phasing, and film speed are determined by a timing disk. The timing disk, main drive gear, and d c motor are on a common shaft. The timing disk has two sets of slots, an outer row of five equally spaced slots, and an inner pair, of which one is an extension of an outer slot. The inner pair determine the start of exposure while the outer slots are used to phase lock the intermittent motion to the vertical sync in the television signal. For subjective considerations, the intermittent motion is phased so that the picture splice occurs in the middle of the frame. Slot position is sensed by a pair of photo diodes and light source such that the outer slots give rise to pulses at a 60 cycle rate and the inner slots to pulses at a 24 cycle rate. The shuttle cams, drive gear, and sprocket wheel (not shown) are located in the low vacuum space while the timing disk, gear reducer for sprocket wheel, and the d c motor are outside the chamber in air.

The Electronic System

Figure 4 is a simplified block diagram of the electronic system used in the electron beam television recorder to modulate the electron beam.

Film speed and position is determined by the timing disk. The motor servo compares the 60 cps output from the timing disk with the vertical sync derived from the television signal. The 24 cps output

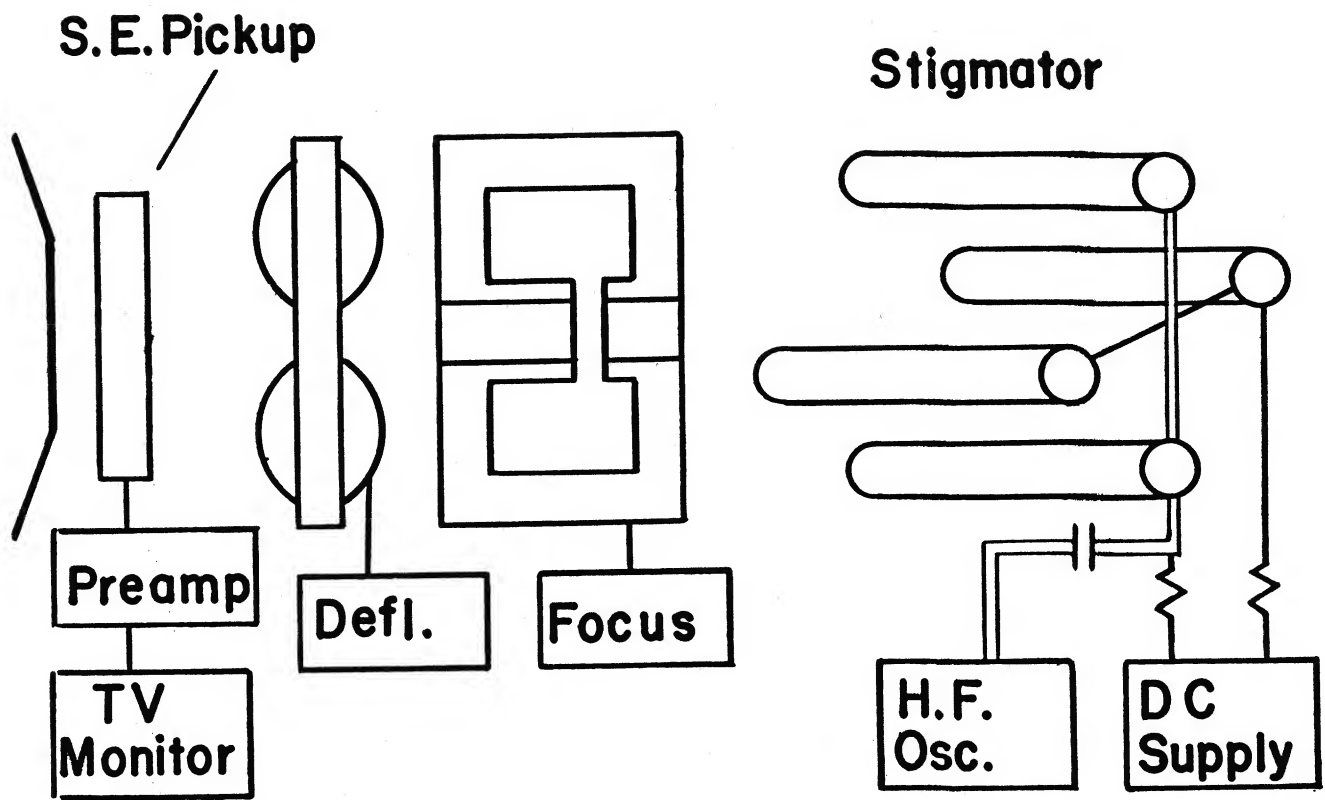
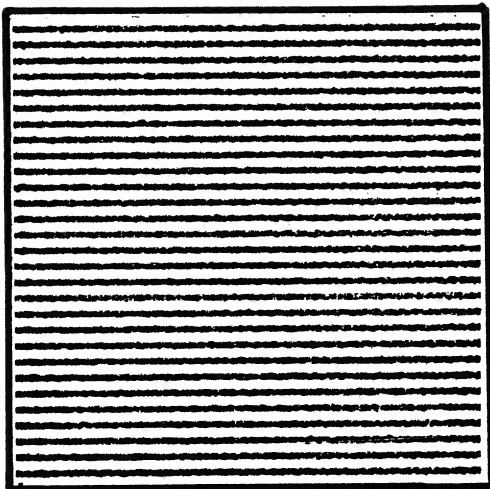


FIG.5 DEFLECTION & FOCUS

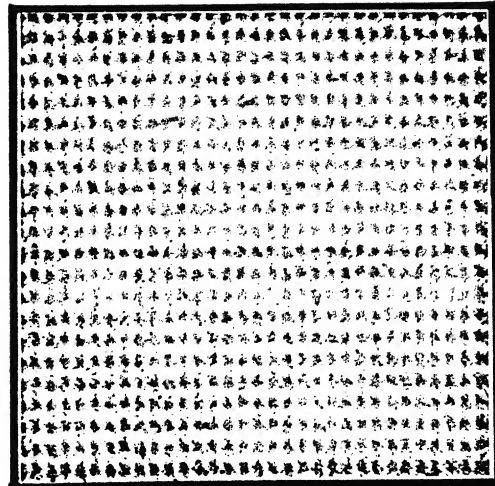
from the timing disk initiates the frame exposure by releasing the inhibit gate on a 525 line integrated circuit counter. The output of the counter and the composite blanking derived from the television signal are fed to an OR gate which is part of the blanking amplifier. Thus the electron beam is released from the Faraday cage and allowed to expose the film for the duration of one frame only after the timing disk says the film is in position.

The electron beam servo control makes use of the horizontal blanking interval when the beam is available for analysis in the Faraday cage. In this interval, the zero beam current level is established. A reference pulse is now generated and fed to the gun grid. The resultant pulse amplitude from the Faraday cage is compared to a reference voltage and any error readjusts the gun bias to restore the pulse height to its proper amplitude. The reference pulse and video signal are fed to the grid by the grid modulator as is the composite blanking signal to establish the minimum or black exposure. Monitoring of the Faraday cage at test point TP by an oscilloscope allows a measurement of the reference pulse during horizontal blanking and of the video signal during the pull down cycle. With this system, we can now measure directly the actual beam used for recording. Figure 5 is a simplified block diagram of the remaining electronic components used to shape and position the electron beam.

The stigmator supply has two parts, a variable d c supply and a fixed high frequency a c supply phase locked to the horizontal sync.



Without Masking



With Masking

FIG. 6 RASTER LINE MASKING

The d c supply is to reduce the fixed astigmatism caused by gun asymmetry errors. The polarity and amplitude of the d c voltage fed to the parallel bars is adjustable. The high frequency signal is used to provide a type of focus modulation which gives the appearance of breaking the line structure of the recorded raster into a dot like pattern with some loss of vertical resolution but little loss of horizontal resolution as shown in Figure 6. This simulated dot pattern is needed when played in certain TV film chains where the increased vertical resolution in the recording system gives rise to a moire pattern resulting from the rescanned raster lines beating with the recorded raster lines. The oscillator frequency is about 8 mc and is phase locked to the horizontal sync so that the dot like pattern is consistent.

The focus and deflection are both magnetic and conventional transistor supplies are used.

The purpose of the secondary emission ring is to aid in focusing the electron beam. The secondary electrons emitted from a surface in the target or film plane are collected by the secondary emission ring, amplified, and fed to a standard television monitor. With a conductive target material, the variation in the secondary emission presents an electron picture of the surface and beam focus can be readily adjusted for maximum detail. Once the focus is set, it need not be readjusted as the focus supply is a very stable current regulated type.

Operation of the electron beam television recorder requires a minimum of mechanical vibration of the film and electron gun. Magnetic and electrostatic effects that deflect the electron beam must also be minimized so that near perfect interlace can be achieved. With the resolution obtainable in this system, slight departures from perfect interlace give rise to severe banding in the recorded picture. Noise in the recorded picture, aside from noise in the television signal, is due to noise of the photographic emulsion and the noise in the electron beam. Analysis and measurements of these types of noise are available in the literature. The fixed noise pattern of the phosphor has been removed in this recording system. Elimination of the phosphor has also provided an increase in resolution, and the absence of the shading problem at the picture splice known as shutter bar.

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